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REPORT ON INTERSTATE POLLUTION OF THE MISSOURI RIVER, YANKTON, SOUTH DAKOTA, TO OMAHA, NEBRASKA

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Report On

INTERSTATE POLLUTION OF THE MISSOURI RIVER YANKTON, SOUTH DAKOTA, TO OMAHA, NEBRASKA

Supplemental to
Water Pollution Series No. 47
and
Water Pollution Series No. 56

Cooperating Agencies

Iowa
Department of Health

Kansas
Board of Health

Missouri
Division of Health

Nebraska
Department of Health

South Dakota
Committee on Water Pollution

U. S. Department of Health, Education, and Welfare
Public Health Service

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16. Abstracts

Interstate pollution data for this section of the Missouri River, prepared at the request of and in cooperation with the stream pollution control agencies of Iowa, Nebraska, and South Dakota, are presented. Sewage and packing plant wastes from the Sioux City-South Sioux City area were found to dominate the pollution of the river, with several small towns contributing minor quantities to add to the total contamination. The data indicate that the tributary streams at their mouths generally carry very minor quantities of bacterial contamination.

17. Key Words and Document Analysis. 17a. Descriptors

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FOREWORD

This report reviews the facts of interstate pollution in the Yankton, South Dakota, to Omaha, Nebraska, section of the Missouri River. It was prepared at the request of and in cooperation with the stream pollution control agencies of the States involved.

Information on which the report is based was assembled from existing reports and files, through discussions with representatives of agencies having responsibilities for and intimate knowledge of various facets of the situation, and by personal observations of the more important features involved.

The following agencies contributed important portions of the assembled material:

State of Iowa

Department of Health
Conservation Commission

State of Nebraska

Department of Health
Game, Forestation and Parks Commission

State of South Dakota

Department of Health

City of Omaha

Omaha Metropolitan Utilities District,
Water Department

City of Yankton

Municipal Water Department

U. S. Government

Corps of Engineers

Missouri River Division
Omaha District
Gavins Point Power Plant
Sioux City Material Yard

Public Health Service

Region VI Office
Robert A. Taft Sanitary Engineering Center

Responsibility for assembling and interpretation of data and preparation of the report was assigned to F. W. Kittrell, In Charge, Stream Sanitation Studies, Robert A. Taft Sanitary Engineering Center.

INTERSTATE POLLUTION OF THE MISSOURI RIVER - YANKTON, SOUTH DAKOTA TO OMAHA, NEBRASKA

BACKGROUND

The Missouri River rarely does things by halves. In many ways it is one of the most unique, one of the best, or one of the worst of our rivers.

It is the longest river in our Nation, traveling 2,500 miles from its headwaters on the Continental Divide to its junction with the Mississippi at St. Louis. It drains one of our Nation's largest river basins, which covers one-sixth of the land area of the United States. It has been one of the most restless of rivers, not only constantly seeking new courses within its own channel but often cutting entirely new channels and sometimes creating interstate problems in the process. It had been one of the wildest in times of flood before it was brought under control by a series of man made lakes that are among the largest in our Country. It has been one of the muddiest, justifying its nickname, the "Big Muddy." It is one of the most contaminated of our rivers used extensively for municipal water supplies. It is one of our most unique rivers in dealing with bacterial contamination, allowing the sewage bacteria to persist for long periods of time and distances in summer and killing them rapidly in winter.

The Missouri's wildness, restlessness, and muddiness long kept its recreational use to a minimum. A Corps of Engineers' channel stabilization program, and large reservoirs upstream from Sioux City are bringing some of its most undesirable traits under control.

The prolonged storage of water in the upstream reservoirs has caused reductions in silt and in coliform organisms typical of sewage pollution, above Yankton. Both control of stream flow by the reservoirs and the channel stabilization program are leading to increased recreational use. Completion of the present channel stabilization program will permit commercial navigation, which now stops at Omaha, to continue upstream to Sioux City.

Many agencies have recognized the critical nature of the pollution of the Missouri, and are actively pursuing a coordinated program to improve water quality.

The Engineering Section of the Missouri Basin Health Council has adopted water quality objectives which define those conditions that constitute pollution of the Missouri River. Members of the Engineering Section, representing the Water Pollution Control Agencies of the ten Missouri Basin States, are requiring their municipalities and industries to provide waste disposal facilities needed to meet those objectives.

The Corps of Engineers has recognized the need of reasonable minimum quantities of water for dilution of wastes as an auxiliary to sewage and waste treatment. The Corps has agreed to maintain a minimum stream flow of approximately 4,000 cubic feet per second (cfs) in the Missouri River above the Platte River to assure the needed minimum dilution. However, operational planning provides for a minimum of 5,000 cfs below Gavins Point Dam. This level of flow is expected to be maintained for the foreseeable future.

Numerous other State and Federal agencies have lent assistance, data and counsel in support of the Clean Water Program for the Missouri River.

The U. S. Public Health Service Region VI Office has served as a coordinator of the basin-wide stream pollution control program. It has provided both technical assistance and consultation to the States and has conducted several meetings to establish the facts regarding interstate pollution and to determine the steps being taken to correct some of the more serious and important interstate problems.

The ultimate responsibility for correction of the pollution lies with the municipalities and industries that produce the pollution. Many have discharged their responsibility through installation of the necessary treatment facilities. Others, including all major cities on the river below Sioux City, are in the midst of activities leading to the same end.

This report deals with an interstate area where the needed action is not being taken.

THE AREA

The section of the Missouri River under consideration extends from Yankton, South Dakota, to Omaha, Nebraska, a distance of nearly 200 miles (Figure 1).

Along its banks lie: Yankton and Elk Point, South Dakota; Sioux City, Iowa; and South Sioux City, Dakota City, and Decatur, Nebraska. On tributary streams near the main stem of the Missouri are Vermillion, South Dakota, and Ponca and Blair, Nebraska.

Of these municipalities, only the small town of Decatur, Nebraska, with a population of 700, has discharged its responsibility for providing sewage treatment.

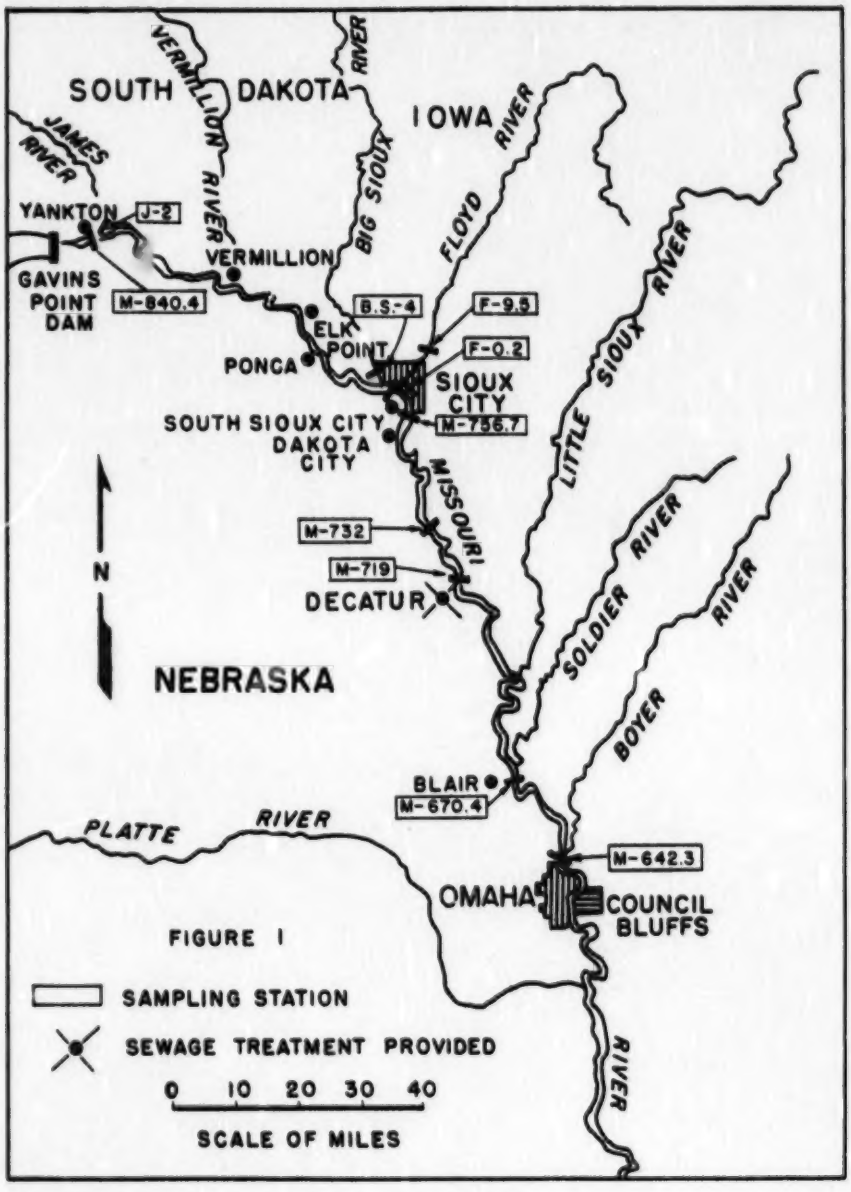

SOUTH DAKOTA
IOWA
NEBRASKA
VERMILLION RIVER
BIG SIOUX RIVER
JAMES RIVER
FLOYD RIVER
LITTLE SIOUX RIVER
SOLDIER RIVER
BOYER RIVER
PLATTE RIVER
MISSOURI
YANKTON
J-2
GAVINS POINT DAM
M-840.4
VERMILLION
B.S.-4
F-9.5
ELK POINT
F-0.2
PONCA
SIOUX CITY
SOUTH SIOUX CITY
DAKOTA CITY
M-756.7
M-732
M-719
DECATUR
BLAIR
M-670.4
M-642.3
OMAHA
COUNCIL BLUFFS
N
SAMPLING STATION
SEWAGE TREATMENT PROVIDED
0 10 20 30 40
SCALE OF MILES

FIGURE 1

Important streams tributary to the Missouri in this section include the James, Vermillion, and Big Sioux rivers above Sioux City in South Dakota, and the Floyd, Little Sioux, Soldier, and Boyer rivers in Iowa between Sioux City and Omaha. Streams tributary to the Missouri on the Nebraska side are few and small.

There are many municipalities on the tributary streams but, with the important exception of Floyd River, sewage treatment, distances from the Missouri, or the small sizes of the towns render them relatively unimportant in contamination of the Missouri River.

SOURCES OF POLLUTION

Between Yankton and Omaha the raw sewage from about 92,000 persons living on or near the banks of the river enters the Missouri.

In addition, numerous industries with an oxygen demand population equivalent of 400,000 dump their wastes into the river. The industrial wastes from towns other than Sioux City, Iowa, are only a small portion of the total problem.

Sewage

The following table shows the sewered populations from which untreated sewage is discharged to the Missouri River in the section under consideration.

Table 1

Sewered Populations

State	Town	Estimated Sewered Population	Percent from State
South Dakota	Yankton	7,200	14.7
	Vermillion	5,000	
	Elk Point	1,350	
Nebraska	Ponca	1,020	9.2
	South Sioux City	3,500	
	Dakota City	600	
	Blair	3,290	
Iowa	Sioux City	70,000	76.1
Total		91,960	100

Practically four-fifths of the raw sewage reaching the river comes from the Sioux City-South Sioux City area. Of the total from all sources, 15.8 percent enters the river above this area, and only 4.2 percent enters between here and Omaha.

Industrial Wastes

Available information indicates that industrial wastes from towns other than Sioux City are equivalent to the sewage from only 4,600 persons.

The consulting engineer who has prepared preliminary sewage treatment plans for Sioux City sampled and analyzed wastes from the packing house sewers along Floyd River during a study of the sewerage system in 1955-1956. These data show that the oxygen demand of these wastes was equivalent to that of raw sewage from 383,000 persons. The 1952 Cooperative State-Federal

Report on Water Pollution in the Lower Missouri Basin (WPS No. 47) showed that other industries in Sioux City produced wastes equivalent to the sewage from 16,100 persons. The present total sewered population equivalent of industrial wastes discharged at Sioux C ity is estimated to be 400,000.

The industrial wastes from all other sources along this section of the main river comprise only a little more than one percent of the total.

Tributary Streams

As is shown in Appendix A, the tributary streams in this area usually carry negligible bacterial contamination at their mouths. Since bacterial contamination is one of the most persistent of the pollutional effects it appears that the tributary streams are not important sources of other types of pollution in the section of the Missouri River under consideration.

WATER USES

The muddy water and the wildness of the Missouri in times past have discouraged extensive use of this section of the river. The Corps of Engineers' programs for control of stream flow by upstream impoundments and for channel stabilization through a system of dikes and revetments have gone far toward correcting these obstacles to increased use of the river.

Use of the Missouri already is increasing and is certain to continue to increase as the Corps' programs reach completion.

Water Supply

Omaha, Nebraska, at the lower end of this section of the Missouri, takes its municipal water supply from the river. This water system serves 330,000 consumers.

The Omaha water treatment plant is of the conventional rapid sand filtration type. Both pre- and post-chlorination are employed. Chlorination is carried to the production of free chlorine residual.

Recreation

Principal recreational uses of the river include boating, fishing, and duck hunting. Some persons, especially children living along its banks, swim in the river.

Duck Hunting

This section of the Missouri is located in one of the major waterfowl flyways of the Country. Duck hunting has long been an important recreational use of the river. Practically every sand bar and spit is occupied by a hunter's blind during hunting season.

Fishing

There is both sport and commercial fishing between Yankton and Omaha. Many persons on both sides of the river hold commercial fishing licenses.

Boating

There is a boat harbor in the Big Sioux River near its mouth, from which pleasure boaters enter the Missouri just above Sioux City for boating

on the main river. There are boat ramps for unloading pleasure boats into the river at Decatur and Blair. A large boat moorage is located just above Omaha, and others are in prospect. Boating is increasing rapidly as the channel stabilization program improves the river for this popular water sport.

Recreational Potential

The Nebraska Game, Forestation, and Parks Commission, realizing the potential of the river for recreation, is initiating a program designed to develop suitable access areas. It is estimated that about 360,000 persons live in Nebraska counties bordering this section of the river, and that over a half million in this State live within driving distances that are considered practical for taking advantage of recreation on the Missouri. The river is the only major body of water in eastern Nebraska and appears destined to be a major center of water sports for this end of the State.

Navigation

The principal navigation on this section of the river at present is that by the Corps of Engineers in their construction program for channel stabilization. The stabilization program was authorized for the purpose of making the river navigable from Omaha to Sioux City. As this program is completed use of the river for commercial navigation will become increasingly important.

HAZARDS TO HEALTH AND WELFARE

Interstate pollution of the Missouri River between Yankton and Omaha produces hazards to health and welfare in the following categories.

1. The hazard of water borne disease caused by the pathogenic bacteria and other harmful organisms that sewage and packing house wastes carry into the river water.

2. Offenses to the senses of decency and well being that result from the visible evidences and odors of pollution.

Bacterial Contamination

Contamination of the Missouri River by sewage bacteria presents health hazards to users of the river for water supply and for recreation.

The Engineering Section, Missouri Basin Health Council, has adopted objectives for control of bacterial quality to protect water users. The Surgeon General has included these objectives in his Comprehensive Program for the Missouri Basin (WPS #56).

1. "For water serving as a source of domestic supply, raw water bacteriological quality should conform to that recommended in 'Manual of Recommended Water Sanitation Practices, 1946, Public Health Bulletin No. 296' pages 11-13." (Raw water receiving treatment such as that provided at Omaha violates the recommended sanitary requirements of the Public Health Service if the average numbers of coliform bacteria exceed 5,000 per 100 ml in any one month, and if more than 5 percent of the samples examined in any one month exceed 20,000 per 100 ml.)
2. "For bathing or swimming waters, monthly arithmetical average 'most probable number' of coliform organisms should not exceed

1,000 per 100 ml during any month of the recreation season; nor exceed this number in more than 20 percent of the samples examined during any such month; nor exceed 2,400 per 100 ml on any day."

3. "For nonbathing or nonswimming waters, the monthly arithmetical average 'most probable number' of coliform organisms should not exceed 5,000 per 100 ml in any month of the recreational season, nor should exceed this number in more than 20 percent of the samples examined during any such month."

Data on bacterial quality of water in the section of the Missouri River from Yankton, South Dakota, to Omaha, Nebraska, are available from several sources. These include:

1. The Cooperative State-Federal Report on Water Pollution, "Lower Missouri River Basin Water Pollution Investigation," October 1952. (WPS No. 47)
2. Daily water plant operating records of the Omaha Metropolitan District, Water Department, for January 1955 through March 1958.
3. "Report on the Water Pollution Investigation at Sioux City, Iowa." Iowa State Department of Health, February 1954.
4. Files of the Iowa State Department of Public Health.
5. Files of the South Dakota Department of Health.
6. U. S. Public Health Service National Water Quality Basic Data Program.

7. Cooperative project of the Omaha Water Department and the U. S. Public Health Service for special bacteriological examinations of water samples.

The 1952 Cooperative State-Federal Report, based on field work in 1950, provides the widest coverage of bacterial quality available for the section of the river under consideration. A technical analysis of the data in that report is given in Appendix A. This analysis shows that bacterial contamination of the Missouri River by surface runoff and by sewage pollution on tributary streams is of relatively minor importance. It also shows that most of the bacterial contamination of the Missouri River between Yankton and Omaha, and at the Omaha water plant, originates in the Sioux City-South Sioux City area. Of the contamination from this area it is estimated that Sioux City sewage contributes 64.5 percent, South Sioux City sewage 3.2 percent, and the packing plants in Sioux City 32.3 percent. The combined sewage bacteria from the area, including those from the packing plants, are estimated to be 85.5 percent of the total from all sources of contamination on or near the river between Yankton and Omaha.

The daily bacteriological results from the operating records of the Omaha Water Department provide detailed data on water quality at the lower end of the section of the Missouri River under consideration. These data combined with those from the 1952 State-Federal Report provide the principal basis for evaluation of bacterial water quality in this report. Data from the other sources listed have been used for supplementation or confirmation as needed.

Median summer and winter concentrations of sewage bacteria (coliform organisms) in this section of the river, taken from the 1952 report, are presented in Figures 2 and 3. Monthly averages of the daily results from the Omaha water plant and the percentages that daily values in each month exceed 20,000 per 100 ml are shown in Figure 4.

This report deals with the Missouri River only as far downstream as the Omaha water plant. However, residual effects of contamination from the Sioux City-South Sioux City area pass Omaha to join the load of pollution contributed to the river by Omaha and Council Bluffs, Iowa. Below these cities the residual contamination from the Sioux City-South Sioux City area exerts its proportional share in effects on downstream water uses.

Effects on Omaha Water Supply

Figure 2 illustrates the direct relationship between sewage bacteria discharged to the Missouri in the Sioux City-South Sioux City area and the bacterial contamination at the Omaha water plant intake during the summer of 1950. The smooth shape of the curve between Sioux City and Omaha indicates that there was no important contribution of sewage bacteria from surface run-off or sewered communities on tributaries in this section of the river. The sewage bacteria added to the Missouri River by Dakota City and Blair combined averaged an estimated 1,800 per 100 ml. Surface runoff and sewered communities on tributaries added an average of about 900 per 100 ml. These estimates make no allowance for decreases in sewage bacteria by natural purification in the river between points of entry to the river and Omaha.

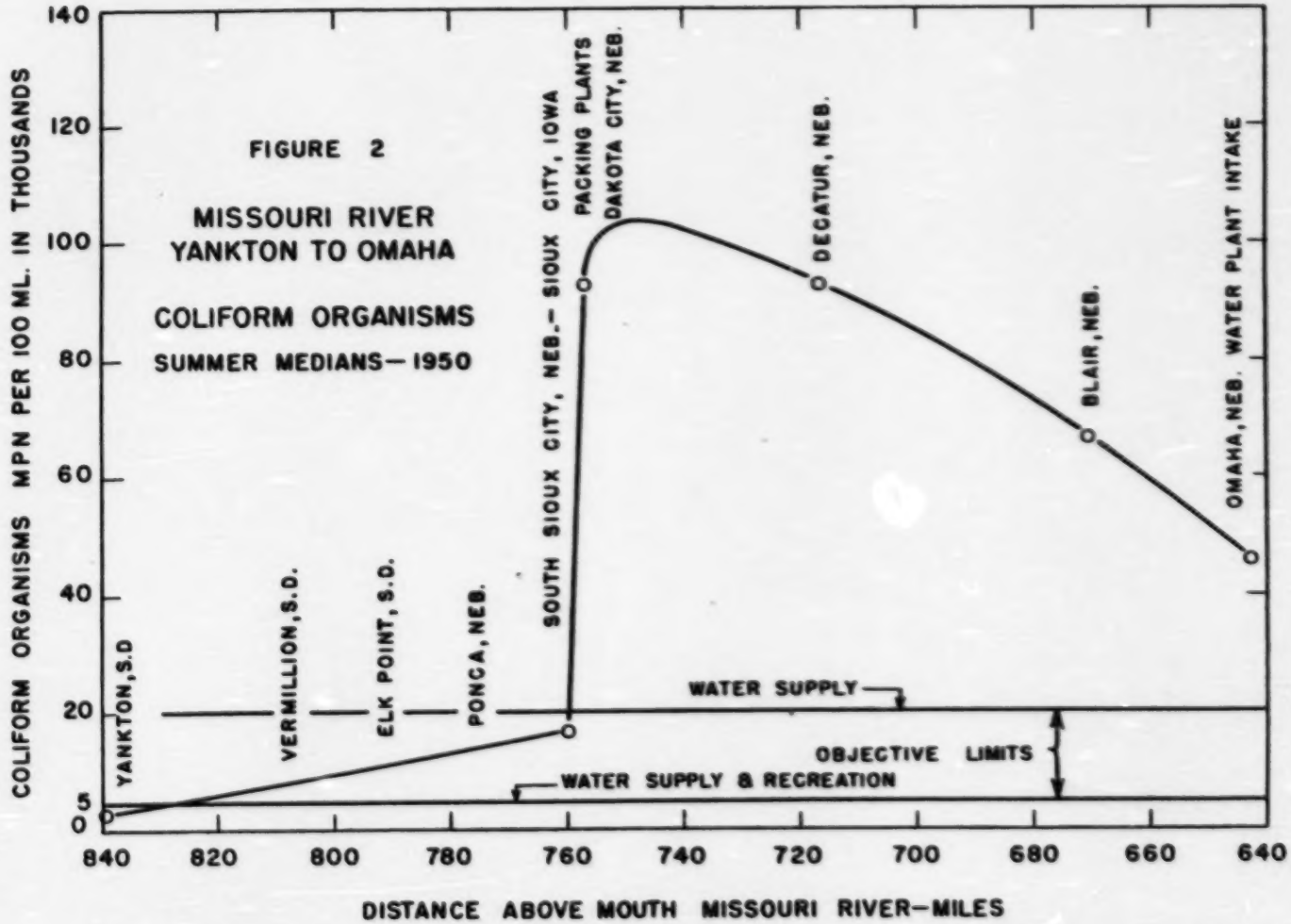


FIGURE 2
MISSOURI RIVER
YANKTON TO OMAHA
COLIFORM ORGANISMS
SUMMER MEDIANS—1950
COLIFORM ORGANISMS MPN PER 100 ML. IN THOUSANDS
140
120
100
80
60
40
20
5
0
YANKTON, S.D
VERMILLION, S.D.
ELK POINT, S.D.
PONCA, NEB.
SOUTH SIOUX CITY, NEB.- SIOUX CITY, IOWA
PACKING PLANTS
DAKOTA CITY, NEB.
DECATUR, NEB.
BLAIR, NEB.
OMAHA, NEB. WATER PLANT INTAKE
WATER SUPPLY
OBJECTIVE LIMITS
WATER SUPPLY & RECREATION
840
820
800
780
760
740
720
700
680
660
640
DISTANCE ABOVE MOUTH MISSOURI RIVER—MILES

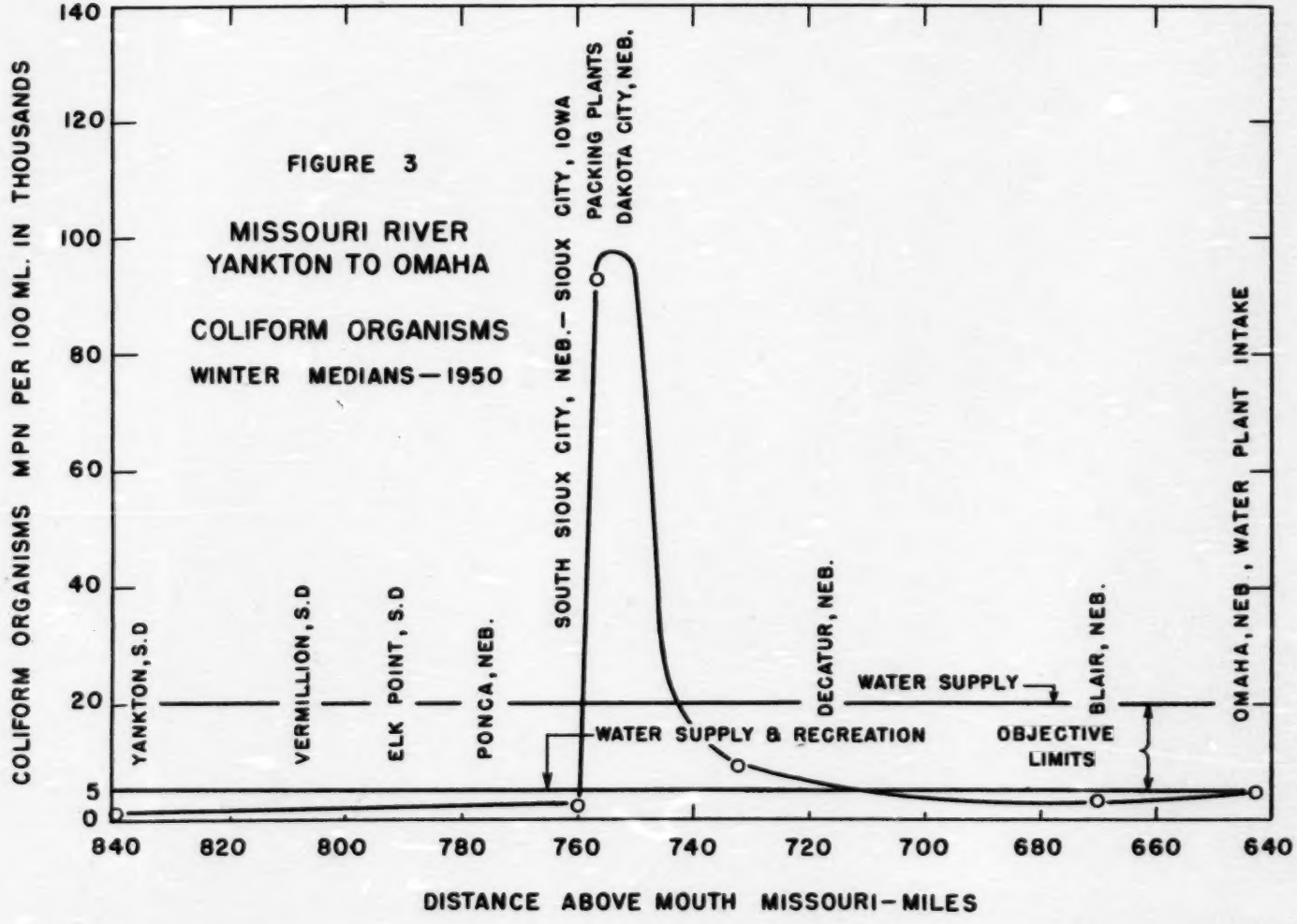


FIGURE 3
MISSOURI RIVER
YANKTON TO OMAHA
COLIFORM ORGANISMS
WINTER MEDIANS—1950
COLIFORM ORGANISMS MPN PER 100 ML. IN THOUSANDS
140
120
100
80
60
40
20
5
0
840
820
800
780
760
740
720
700
680
660
640
DISTANCE ABOVE MOUTH MISSOURI—MILES
YANKTON, S.D
VERMILLION, S.D
ELK POINT, S.D
PONCA, NEB.
SOUTH SIOUX CITY, NEB.— SIOUX CITY, IOWA
PACKING PLANTS
DAKOTA CITY, NEB.
DECATUR, NEB.
BLAIR, NEB.
OMAHA, NEB., WATER PLANT INTAKE
WATER SUPPLY
WATER SUPPLY & RECREATION
OBJECTIVE
LIMITS

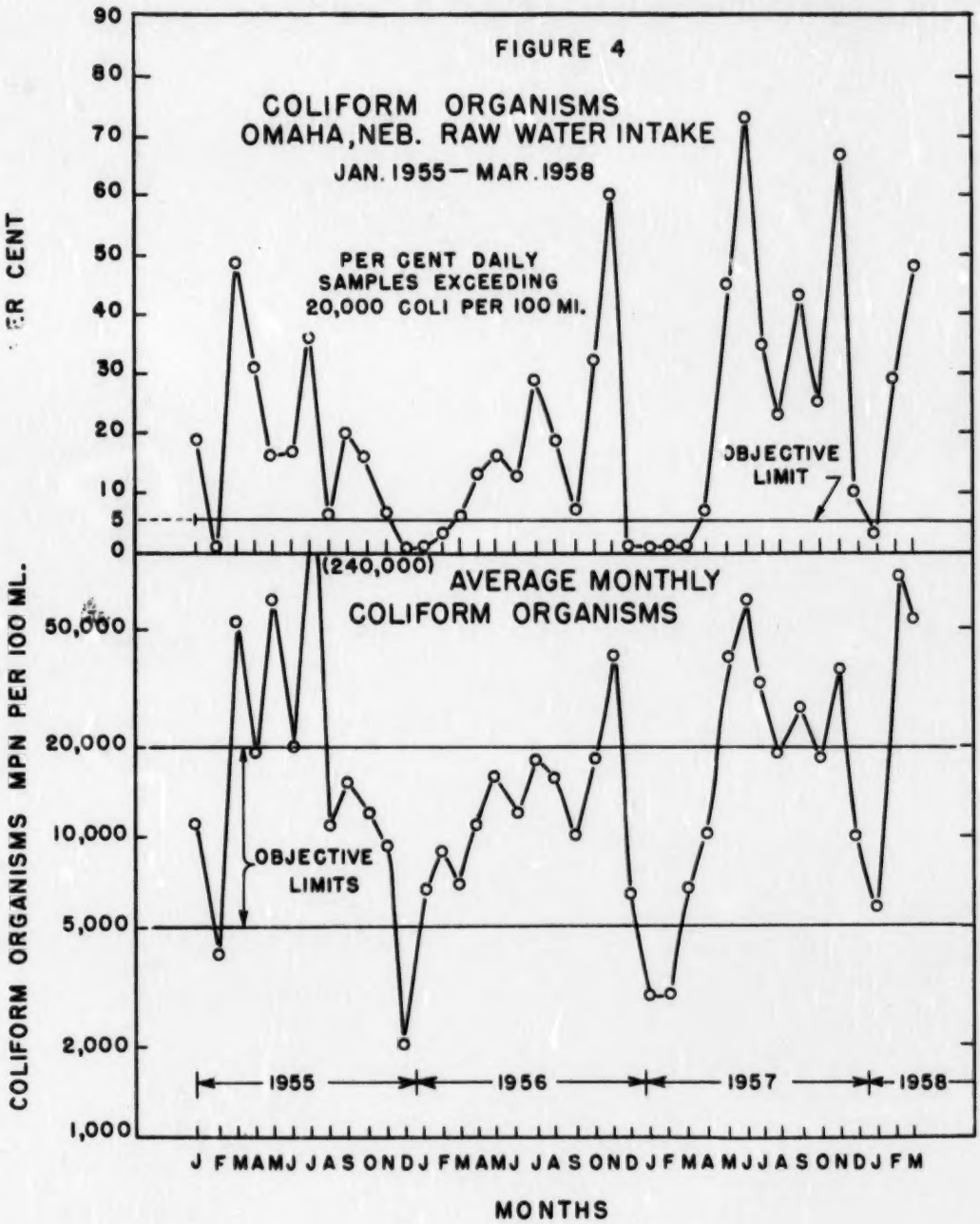


FIGURE 4
COLIFORM ORGANISMS
OMAHA, NEB. RAW WATER INTAKE
JAN. 1955 — MAR. 1958
PER CENT DAILY SAMPLES EXCEEDING 20,000 COLI PER 100 ML.
OBJECTIVE LIMIT
PER CENT
90
80
70
60
50
40
30
20
10
5
0
(240,000)
AVERAGE MONTHLY COLIFORM ORGANISMS
OBJECTIVE LIMITS
COLIFORM ORGANISMS MPN PER 100 ML.
50,000
20,000
10,000
5,000
2,000
1,000
1955
1956
1957
1958
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M
MONTHS

If there had been large additions of contamination, major irregularities in the curve would have occurred.

The numbers of sewage bacteria at the Omaha water plant in 1950, 43,000 per 100 ml (Figure 2), were well within the range of summer monthly averages for 1955 through 1957 at the Omaha water plant (Figure 4). These averages ranged from a minimum of 11,000 per 100 ml to 246,000 per 100 ml. The majority of monthly averages during 1955 through 1957 were in the range of 15,000 to 60,000 per 100 ml. This indicates that the 43,000 per 100 ml value for 1950 was reasonably representative of actual conditions at that time.

Figure 3 indicates that sewage bacteria died off very rapidly below the Sioux City area in the winter of 1950. Here again there was reasonable agreement between the 4,400 per 100 ml value found then at the Omaha water plant, and the range of monthly averages at the plant in 1955 through 1957 (Figure 4). These averages ranged from 2,000 to 78,000 per 100 ml, with the majority of the values in the range of about 3,000 to 7,000 per 100 ml.

Of the 39 monthly averages included in Figure 4, 35 exceeded the Engineering Section, Missouri Basin Health Council, objective for average bacterial quality of a source of domestic water supply with the type of water treatment provided at Omaha. In 30 months more than 5 percent of the daily values exceeded 20,000 per 100 ml. The average value of all the summer monthly averages for sewage bacteria at Omaha during the three years was 38,600 per 100 ml.

Sewage bacteria in the river water occasionally have survived the plant's treatment processes to enter Omaha's distribution system. In order

to combat this hazard, the water department has revised the chlorination facilities at the treatment plant at a cost of $50,000. In addition, several expensive chlorine residual recording instruments have been installed at selected points in the treatment process to maintain a continuous check on adequacy of the chlorination process. Adequate chlorination is the most effective single treatment barrier against the excessive bacterial contamination carried by the Missouri River water. Chlorine is applied at three separate points in the treatment process. If this barrier should be eliminated through mechanical failure or operating error for even a short time the remaining treatment processes would be unable to cope effectively with the highly contaminated river water, and an epidemic of water borne disease almost certainly would follow in Omaha.

Effects on Recreational Uses

It has been shown earlier in the report that there is duck hunting, boating, fishing, and some swimming on the Missouri in the section under consideration. All of these sports involve some contact by the sportsman with the sewage contaminated river water that could cause water borne disease.

Reference to items 2 and 3 of the Engineering Section's water quality objectives and to Figures 2 and 4 indicate that the Missouri River between the Sioux City area and Omaha was unsuitable for any of the recreational uses, with the possible exception of duck hunting between Decatur and Omaha. The duck hunting season is in November and the winter curve (Figure 3) on sewage bacteria probably applies reasonably well to November conditions. The average monthly sewage bacteria concentrations at Omaha exceeded the

basic objective of 5,000 per 100 ml during every summer month of the three years, 1955 through 1957. All other objectives were violated in most months. Bacterial concentrations of course were higher above Omaha, mounting continuously on proceeding upstream to the Sioux City-South Sioux City area.

The following figures give an idea of the hazards of recreational use of the Missouri in this section. Just below the Sioux City area a drop of spray from the prow of a motor boat could carry nearly 50 sewage bacteria into the face, nostrils, or mouth of the boater. Anyone swimming or falling into the water in this section and swallowing one mouthful of water would ingest more than 90,000 sewage bacteria. Just above Omaha comparable figures would be about 20 sewage bacteria per drop and 40,000 per mouthful.

Those who use the Missouri for recreation cannot be expected to know the health hazards to which they expose themselves by contact with the contaminated river water. Their understandable lack of information concerning the true hazards are illustrated by the fisherman observed near Missouri Valley, Iowa, just above Omaha. He dipped a bucket of the muddy Missouri River water, let it settle a while, and proceeded to drink it. When asked by the Public Health Service observer if he was not afraid it would make him sick, he said that the mud in the river ground the germs to death.

Effects on Navigation

The Engineering Section's water quality objectives do not include one for navigation. Navigation involves contact with the river water similar to that encountered in boating and fishing. Item 3 of the objectives may reasonably be applied for navigation.

The Corps of Engineers employees who transport and install materials in connection with the river stabilization project are exposed to essentially the same health hazards because of sewage bacteria as are those who use the river for recreation.

Offenses to Decency and Welfare

The Missouri River in the vicinity of Sioux City-South Sioux City was observed during a boat trip in April 1958. Additional information on nuisance conditions resulting from pollution was obtained by discussions with employees at the Omaha water treatment plant and with other individuals familiar with the river. Several offensive conditions were observed and the occurrence of others was described by qualified persons.

The Engineering Council adopted objectives for control of nuisance conditions.

1. "Removal of settleable and floating solids to prevent sludge banks, floating materials, and nuisance conditions should be required as the minimum acceptable treatment" (of sewage).
2. "For industrial wastes similar in nature to municipal wastes, treatment should be based on the same premise as recommended for municipalities."

It is estimated that the sewage discharged from Sioux City and South Sioux City carries about 10 tons of human feces and 18,000 gallons of urine into the river each day. No estimate is available on similar materials from the packing plants.

Along the Sioux City waterfront the evidences of untreated sewage and packing house wastes were obvious.

At the mouth of the Perry Creek sewer, just below Combination Bridge, the water appeared grey, floating feces and other sewage solids were obvious, and gas bubbles from sludge deposits rose to the surface. Odor typical of stale sewage could be detected for some distance from the mouth of the sewer.

The mouth of Floyd River was almost clogged with untreated packing house wastes. Floating masses of grease and solids, apparently from paunch manure, lined the banks, extended well into the stream, and clung to every solid object on the surface of the stream. Where the water was not red with bloody wastes it was grey from decomposing organic wastes. Gas bubbles rose from sludge deposited on the bottom. Offensive odor filled the atmosphere.

In its channel stabilization program the Corps of Engineers has built revetments in the river roughly parallel to the shore and about 50 to 100 feet out from the bank. These revetments are joined to the river bank at intervals by other short revetments perpendicular to the bank. This installation, which resembles large tanks built into the river, extends upstream from the mouth of Floyd River for about one mile.

Several sewers, some of which apparently carried industrial wastes, discharged untreated wastes into these pools. This condition has created, in effect, a mile-long series of giant septic tanks along the Sioux City waterfront. The offensive conditions created by the discharge of sewage and industrial wastes into this confined area of the river can be described only in terms of open septic tanks. Masses of scum and debris, typical of

the refuse of a large city, cover large portions of the surface. When the water can be seen it is grey and lifeless except for the rising bubbles of putrefaction. Odor typical of septic organic wastes pervades the atmosphere.

Below the Sioux City-South Sioux City area floating particles of grease were observed for several miles downstream. In some eddy areas objectional floating materials had collected.

Effects on Omaha Water Supply

At the Omaha water plant two visible effects of upstream pollution occur.

On occasion the metal screens which protect the pumps in the water intake structure at the river against floating materials become covered with grease. This grease contained animal hairs, which indicate its origin in the meat packing plants upstream. The grease accumulates on the screens most often in the late fall when river temperatures are dropping rapidly.

The screens do not remove all of the grease and some of it passes into the water treatment plant to float on the surface of and coat the walls of concrete basins used in treating the water.

At times large numbers of condoms accumulate on the water intake screens. Some of these, also, escape the straining action of the screens and pass into the water treatment plant basins. It sometimes is necessary to assign one of the plant operators responsibility for dipping the condoms from the basins. They reach the plant in greatest numbers during the period immediately following the break-up of ice in the river. Apparently they are trapped and accumulate in pockets in the ice covered river during

winter and are flushed out when the river frees itself from ice and again can flow freely.

This situation is a violation of the water quality objectives of the Engineering Section for both sewage and industrial wastes, which require removal of floating solids that cause nuisance conditions.

Effects of Recreation and Navigation

Anyone taking to the river, in the Sioux City-South Sioux City area, in pursuit of pleasure through boating, fishing, duck hunting, or swimming, or of duties allied with navigation is subjected to the objectionable sights and odors along the Sioux C ity waterfront. The obvious defilement of the water detracts from the pleasure and relaxation that most people achieve through close association with a body of water. The odor from the putrefying wastes along the waterfront further reduces the enjoyment to be obtained from the river in this section.

The completion of the proposed interstate highway along the Sioux City waterfront will expose the traveling public to the offensive conditions existing there.

It has been reported (WPS #47) that the Missouri above heavy sources of pollution produces catfish, ling, walleyed pike, (sauger) and sturgeon and that "predominance of carp appears to characterize only the lower, heavily polluted reaches of the river below Sioux City."

Commercial fishermen using nets for several miles below the Sioux City-South Sioux City area have complained that the nets become clogged with grease.

SUMMARY

Sewage and packing plant wastes from the Sioux City-South Sioux City area dominate the pollution of the Missouri River between Yankton, South Dakota, and Omaha, Nebraska. Several small towns on or near this section of the main river contribute minor quantities of pollution that add to the sum total of contamination. These towns include: Yankton, Vermillion, and Elk Point in South Dakota, and Ponca, Dakota City, and Blair, Nebraska.

The Sioux City-South Sioux City area contributes an estimated 85.5 percent of the total bacterial contamination discharged directly to the river between Yankton and the Omaha water plant. Of the contamination from this area sewage from Sioux City, Iowa, is responsible for 64.5 percent, industrial wastes from the packing plants in Sioux City for 32.3 percent, and sewage from South Sioux City, Nebraska, for 3.2 percent.

Available data indicate that the tributary streams at their mouths generally carry very minor quantities of bacterial contamination. Their flows, in fact, provide some dilution of the high bacterial content produced in the main river by wastes from the Sioux City area.

The bacterial death rate in the Sioux City to Omaha section of the river is extremely low during summer. This is an important factor in the excessive contamination by sewage bacteria that persists from Sioux City to the Omaha water plant.

During 35 of 39 months (January 1955 through March 1958) bacterial contamination at the Omaha water plant exceeded the water quality objectives of the Engineering Section, Missouri Basin Health Council. In addition,

grease, mixed with animal hair, and condoms enter the water treatment plant in quantities. Untreated sewage and industrial wastes from the Sioux City-South Sioux City area are principally responsible for the health hazards and indignities imposed on the water supply of 330,000 persons in Omaha.

Those who use the river in the Sioux City to Omaha section for boating, fishing, duck hunting and swimming, and for navigation are exposed to the health hazards of excessive bacterial contamination which is many times the limits for recreational use of water adopted by the Engineering Section. In the vicinity of Sioux City those who go on the river or near the waterfront are offended by the sight of masses of floating solids from sewage and industrial wastes, and by the odors of putrefaction from the river near the points of waste discharge.

It is evident that pollution of the Missouri River in and below the Sioux City-South Sioux City area constitutes pollution of interstate waters subject to abatement under the Federal Water Pollution Control Act as such pollution endangers the health and welfare of persons in States other than those in which the discharges contributing to such pollution originate.

APPENDIX A

TECHNICAL ANALYSIS OF 1950 BACTERIOLOGICAL DATA

In the report, Lower Missouri River Basin Water Pollution Investigation (1952), the bacteriological data obtained during 1950 are reported as most probable numbers (MPN) of coliform organisms per 100 milliliters (ml) of water.

The term "most probable numbers" signifies that the method of examination does not yield a direct quantitative result. Statistical procedures are applied to the results of laboratory observations to determine what number of bacteria is most apt to produce the combination of observed results. The procedure has been found to yield results in satisfactory agreement with a recently developed method for making direct quantitative counts of the bacteria.

The term "coliform organisms" applies to a group of bacteria which typically are of fecal origin. For practical purposes the term may be translated roughly, though with some loss of specificity, into the more readily understood term, "sewage bacteria." Where this term is used in this report it is understood to refer to coliform organisms.

The volume unit, 100 ml, is approximately one-fifth of a pint, or one large mouthful, of water.

Interpretation of the bacteriological data on streams is simplified if the MPN results, combined with stream flows, are converted to a common basis which permits direct comparison of the stream results with the sources

of waste. By use of appropriate factors(1) the coliform data at any point on a stream may be converted to equivalent numbers of persons required to produce raw sewage containing the same total number of coliform organisms. This "bacterial population equivalent" is designated in this report as the B.P.E., to distinguish it from the better known P.E. based on oxygen demand.

The analysis of the data was undertaken to assess the contributions to bacterial contamination by the packing house wastes, by surface runoff, and by sewage pollution on tributary streams, and to evaluate patterns of behavior of bacterial contamination in the Missouri River.

The 1952 report summarizes the data on the basis of three periods of the year, summer, winter, and intermediate. These periods include June through September, December through February, and October, November, March, April and May, respectively.

Tables A-1 and A-2 present the summarized data for the three periods in terms of B.P.E.'s. Both median and average values for the periods were examined. The median values for the main river were selected for analysis

(1) Summer:

$$B.P.E. = Q(cfs) \times MPN(\text{per } 100 \text{ ml}) \times (6.1 \times 10^{-5})$$

Winter and Intermediate:

$$B.P.E. = Q(cfs) \times MPN(\text{per } 100 \text{ ml}) \times (2.45 \times 10^{-4})$$

because they yielded results more nearly in line with other known factors in the situation. Average values were used in the analysis of the tributary stream data because they appeared to yield more reasonable evidence than median values on surface runoff and contamination from sewered towns on the tributaries.

In general the intermediate values, representing 5 months of the year, during which stream flows were irregular and temperatures were variable, yielded erratic results on the main river which do not lend themselves to reasonable interpretation. Only 5 samples were collected at each station for this period, and these apparently were insufficient to assure correlation of the intermediate period data.

The data for the four month summer period and the three month winter period generally appear reasonable and yield considerable information of value.

Table A-1 presents detailed B.P.E. information on three of the major tributaries of this section of the river, the James, the Big Sioux, and the Floyd. These three rivers comprise 32,495 square miles, or 75.0 percent, of the 43,300 square miles of total area that drains to the Missouri River between Yankton and Omaha.

The James River at its mouth carried average B.P.E.'s of 22 during the summer, 2 during the winter, and 1,326 during the intermediate period. Maximum average values for the three rivers were 1,387 in summer and 1,956 in winter in the Floyd, and 1,319 in the intermediate period in the James. The totals for all three rivers averaged 1,682 in the summer, 1,982 in the winter and 1,883

in the intermediate period. None of these values is as great as the sewage bacteria discharged directly to the Missouri from the 3,500 persons in South Sioux City alone.

It may be assumed that the total B.P.E. discharged from the entire drainage area tributary to this section of the Missouri is in direct proportion to the B.P.E.'s discharged from the drainage area represented by the three tributaries. On this bases the total contribution of sewage bacteria to the main river from the entire drainage area becomes 2,240 B.P.E. in summer, 2,640 in winter, and 2,442 in the intermediate period.

Even if the maximum daily B.P.E. from each tributary be selected, regardless of season, the maximum observed total from the three tributaries was 14,280 B.P.E. The computed maximum for the entire tributary drainage area would be 19,021. Even this maximum, which rarely occurs, is less than one-third of the average daily discharge from Sioux City's 70,000 sewered population.

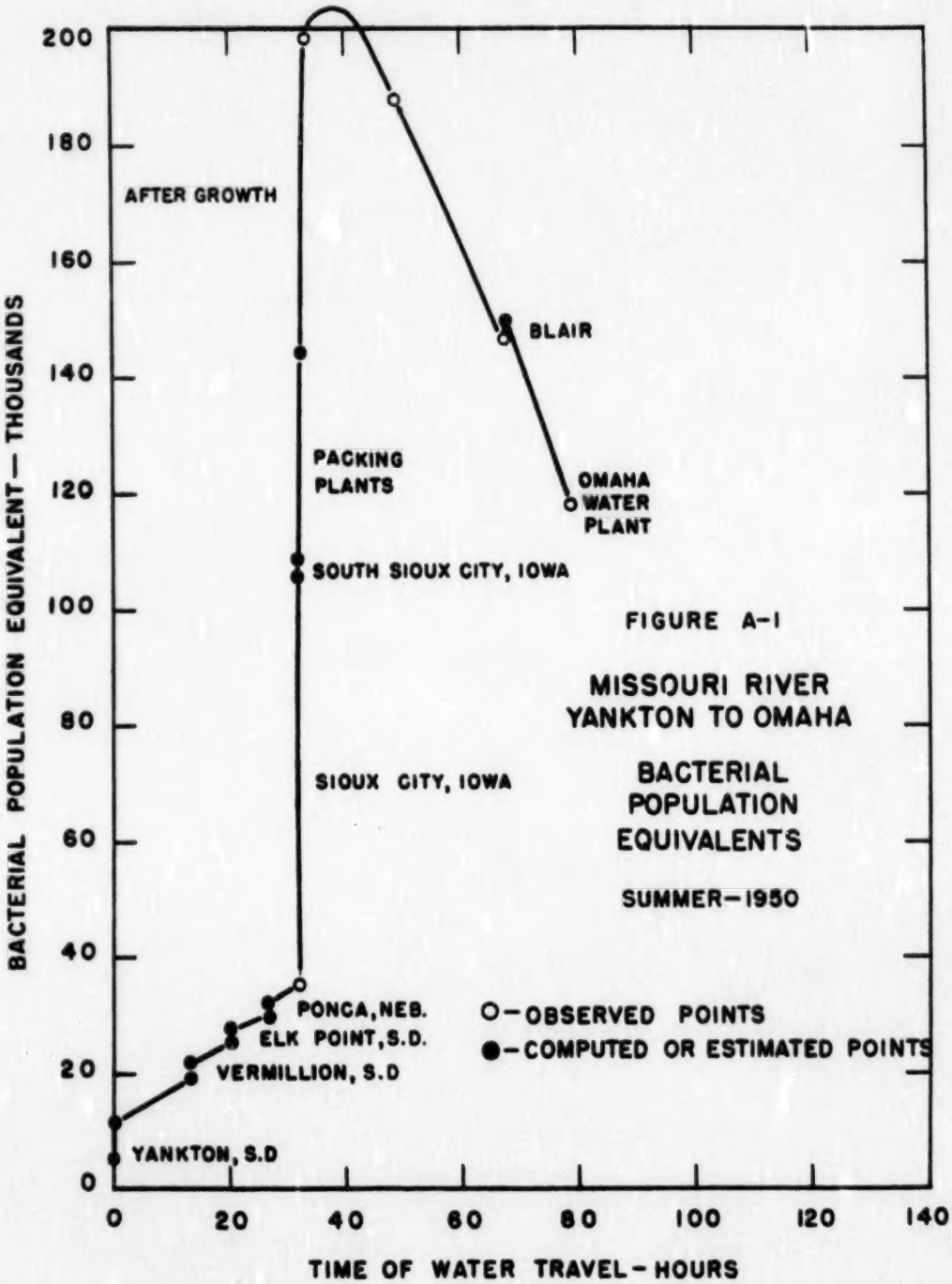
The foregoing analysis of the data on sewage bacteria carried by the tributary streams shows that generally negligible contamination enters the Missouri from surface runoff and from sewered towns on tributaries. It is probable that there are occasional periods of a few days when high rainfall and heavy runoff over a large portion of the basin does bring excessive bacterial contamination from the drainage basin into the main river. If this occurred frequently it should have showed up in some of the results of the 66 samples taken on the three tributaries. In addition, examination of daily bacterial records on raw water of the Omaha water plant indicates

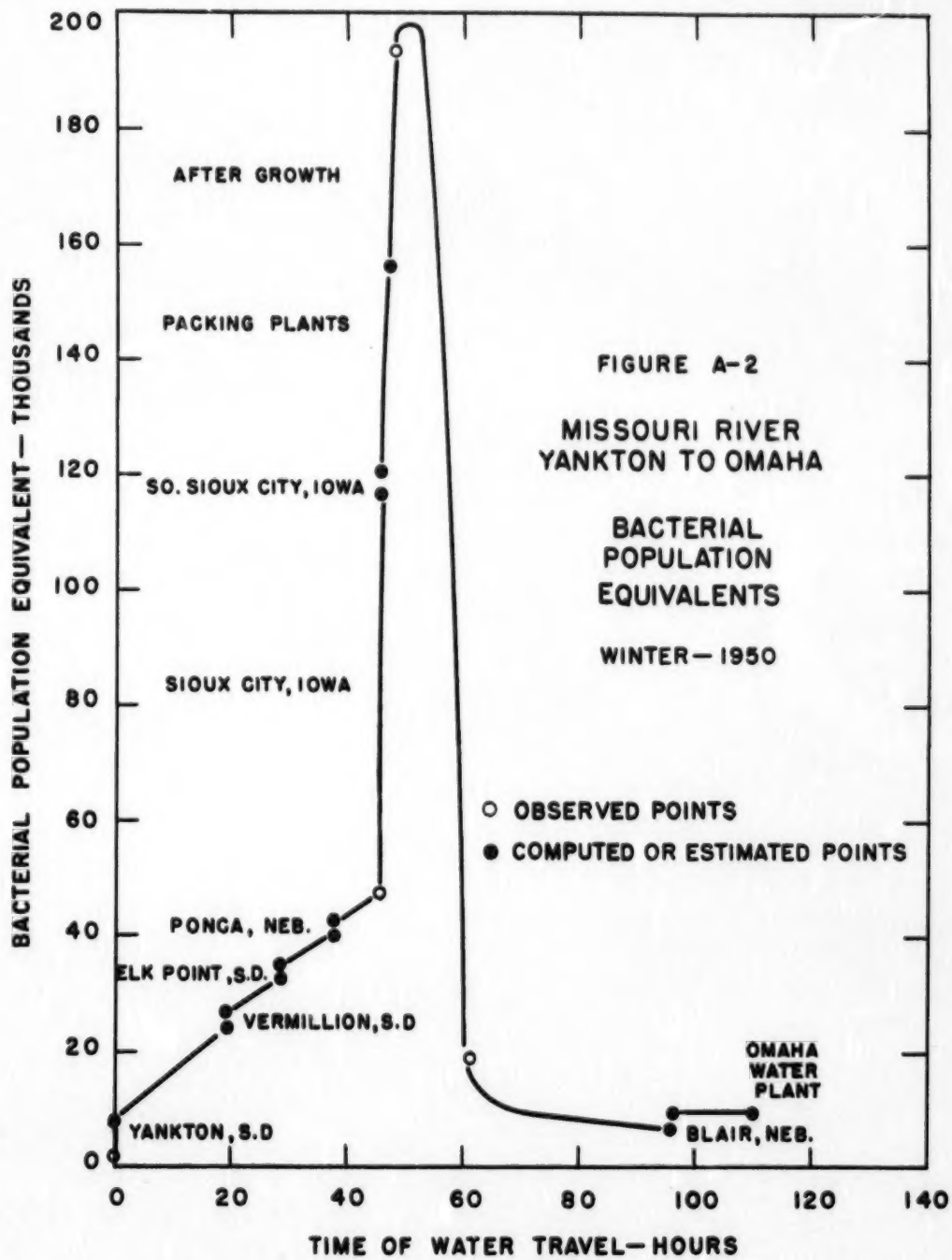
that the heavy surface runoff probably affected the sewage bacteria content of the water at Omaha on only 38 days during the period, January 1955 through March 1958, or 3.2 percent of the time. For 96.8 percent of the time the principal source of bacterial contamination of the raw water at Omaha was pollution from the Sioux City-South Sioux City area.

The summer and winter data in Table A-2 are presented graphically in Figures A-1 and A-2.

The summer data indicate (Figure A-1) that the river above Yankton carried sewage bacteria equivalent to the raw sewage from 4,550 persons. There is a drainage area of 222,000 square miles between this point and Ft. Peck Dam upstream. The impoundment of Lewis and Clark Lake, by Gavins Point Dam, and of other upstream reservoirs since 1950 has reduced the contamination of the river above Yankton. Data obtained by the South Dakota Department of Health on the river water at the Yankton municipal water supply intake during 1956 and 1957 indicated that the summer B.P.E. has dropped to 100. Data from the National Water Quality Basic Data Program confirm this very low B.P.E. above Yankton.

Below Sioux City (Figure A-1) the data indicate a normal increase to 199,000 B.P.E. Of this increase it is estimated that Sioux City contributed 70,000 B.P.E. (the sewered population in 1950), South Sioux City 3,500 B.P.E., and the packing plants 35,000 B.P.E. The remainder of 54,800 is attributed to the usual aftergrowth of sewage bacteria that follows discharge of raw sewage to a stream.


BACTERIAL POPULATION EQUIVALENT — THOUSANDS
200
180
160
140
120
100
80
60
40
20
0
AFTER GROWTH
BLAIR
PACKING PLANTS
OMAHA WATER PLANT
SOUTH SIOUX CITY, IOWA
SIOUX CITY, IOWA
PONCA, NEB.
ELK POINT, S.D.
VERMILLION, S.D
YANKTON, S.D
0
20
40
60
80
100
120
140
TIME OF WATER TRAVEL - HOURS
FIGURE A-1
MISSOURI RIVER
YANKTON TO OMAHA
BACTERIAL POPULATION EQUIVALENTS
SUMMER—1950
O—OBSERVED POINTS
●—COMPUTED OR ESTIMATED POINTS


BACTERIAL POPULATION EQUIVALENT— THOUSANDS
200
180
160
140
120
100
80
60
40
20
0
AFTER GROWTH
PACKING PLANTS
SO. SIOUX CITY, IOWA
SIOUX CITY, IOWA
PONCA, NEB.
ELK POINT, S.D.
VERMILLION, S.D
YANKTON, S.D
OMAHA WATER PLANT
BLAIR, NEB.
FIGURE A-2
MISSOURI RIVER
YANKTON TO OMAHA
BACTERIAL POPULATION EQUIVALENTS
WINTER— 1950
OBSERVED POINTS
COMPUTED OR ESTIMATED POINTS
0
20
40
60
80
100
120
140
TIME OF WATER TRAVEL— HOURS

The estimated 35,000 B.P.E. for the packing plants was selected from the values shown for these plants in Table A-2, and a fourth value of 49,600 which was computed from data obtained on the Floyd River above and below the packing plants by the Iowa State Department of Public Health in 1952 and 1953. The selected value for the packing plants represents 32.3 percent of the sewage bacteria discharged to the river from the Sioux City-South Sioux City area.

Below Sioux City the curve shows a typical rise to a peak, followed by a reasonably smooth drop to 118,000 B.P.E. at the Omaha water plant intake. The drop is interrupted only slightly by the discharge of raw sewage from 3,290 persons at Blair, Nebraska. The Boyer River exerted no significant effect on the curve, with a computed B.P.E. of only 82 at its mouth.

The drop from 204,000 at the peak of the curve below the Sioux City area to 118,000 at Omaha represents a reduction of only 42.2 percent in 40 hours time of water travel. It is the low rate of bacterial decrease in this section of the Missouri River, rather than contamination from surface runoff, which accounts for the persistence of contamination between Sioux City and Omaha.

The B.P.E. curve for the winter period (Figure A-2) follows trends similar to those for the summer. Essentially the same comments are applicable to both curves with one major exception. The rate of decrease in sewage bacteria between the peak of the winter curve and the first sampling station downstream is much greater than for the summer curve. The indicated winter rate of decrease is 90 percent in 10 hours time of water travel.

The probability that the above death rates represent true conditions in this section of the Missouri River is strongly supported by the evidence presented in the section on bacterial quality in the main text.

Table A-1

Bacterial Population Equivalent of Tributary Drainage Areas

1950

Period	Month	Bacterial Population Equivalent				
		James River	Big Sioux River	Floyd(1) River	Totals: Three Tributaries	Totals: Total Drainage Area (2)
Summer	June	108	262	458		
	July	9	835	9,900		
	Aug.	4	236	454		
	Aug.	8	20	74		
	Aug.	4	25	10		
	Sept.	4	0.1	24		
	Sept.	1	0.6	13		
	Sept.	40	805	160		
	Avg.	22	273	1,387	1,682	2,240
Winter	Dec.	0.1	95	11		
	Jan.	0.01	22	225		
	Jan.	0.1	6	168		
	Jan.	0.1	5	3,530		
	Feb.	0.1	9	73		
	Feb.	12	3	9,580		
	Feb.	1	26	48		
	Avg.	2	24	1,956	1,982	2,640
Intermediate	Mar.	430	578	775		
	Apr.	348	1,050	655		
	May	3,180	1,200	277		
	Oct.	26	377	497		
	Nov.	2	19	0.6		
	Avg.	797	645	441	1,883	2,442
Mar.Apr.May	Avg.	1,319	943	569	2,831	3,771
Maximum Day	Any	3,180	1,200	9,900	14,280	19,021

(1) Above Sioux City.

(2) Estimated for total area tributary to Missouri River between Yankton and Omaha.

Table A-2

Bacterial Population Equivalents of Streams and Sources of Waste

1950

	Bacterial Population Equivalent		
	Season		
	Summer	Winter	Intermediate
Missouri River above Yankton, S.D.(M-840.4)	4,550	1,580	35,600
Yankton, S. D., Sewage (M-840.4)	7,200	7,200	7,200
James River (M-833)	6	0.1	17
Vermillion, S.D., Sewage (M-806.1)	5,000	5,000	5,000
Elk Point, S.D., Sewage (M-790.1)	1,350	1,350	1,350
Ponca, Neb., Sewage (M-774)	1,020	1,020	1,020
Big Sioux River (M-761)	37	22	578
Missouri River above Sioux City (M-760)	35,700(1)	47,800	190,000
Sioux City, Iowa, Sewage (M-760)	70,000	70,000	70,000
South Sioux City, Neb., Sewage (M-760)	3,500	3,500	3,500
Floyd River above Sioux City	114	211	597
Floyd River below Packing Plants (M-758.3)	31,200	2,110	24,100
Packing Plants, Sioux City, Iowa (M-758.3)	31,086	1,899	23,503(4)
Missouri River below Sioux City, Iowa,(M-756.7)	199,000	194,000	380,000
Dakota City, Neb., Sewage (M-753.6)	0(2)	0	0
Missouri River, Olson Landing (M-732)	-	19,400	-
Missouri River, Onawa Material Yard (M-719)	188,000	-	30,900
Decatur, Neb., Sewage (M-716.9)	100(3)	100	100
Missouri River above Blair, Neb.,(M-670.4)	147,000	6,620	93,500
Blair, Neb., Sewage (M-670)	3,290	3,290	3,290
Boyer River (M-651)	82	22	-
Missouri River, Omaha Water Plant (M-642.3)	118,000	9,700	201,000

(1) Results on right quarter samples only used as more nearly representative of river above Sioux City. Middle and left quarter samples probably contained contamination from Sioux City sewers above sampling station.

(2) No sewerage system in 1950.

(3) Treated sewage from 680 sewered population.

(4) Iowa State Department of Health data in 1952-1953 indicated bacterial population equivalent of 49,300.